Research Notes

PRENESTING USE OF INTERTIDAL HABITATS BY PIPING PLOVERS ON SOUTH MONOMOY ISLAND, MASSACHUSETTS

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On barrier islands, piping plovers commonly select nest sites adjacent to bay-side intertidal flats, pools, or other moist substrates that are protected from ocean waves (Patterson et al. 1991, Elias et al. 2000, Keane 2002). During the fledging period, these areas often support more terrestrial arthropods than adjacent ocean beaches (Loegering and Fraser 1995, Elias et al. 2000). Plover chicks in these areas typically forage at higher rates, and they often have higher survival rates than chicks foraging exclusively on backshore and ocean intertidal areas (Loegering and Fraser 1995, Elias et al. 2000). In some places, however, piping plovers nest near protected moist substrates even though physical barriers prevent broods from reaching them (Patterson et al. 1991, Loegering and Fraser 1995, Keane 2002). This suggests that nesting near protected moist substrates is adaptive for adults even if their hatchlings cannot forage there until they fledge.

One possible value of selecting nest sites near protected moist substrates is that these areas may provide a reliable food supply for adults prior to nesting. Protected sandflats, mudflats, and algal flats (sandflats with dense *Lyngbya* spp.) are frequently used by piping plovers wintering in southeast Atlantic and Gulf Coast sites (Johnson and Baldassarre 1988, Nicholls and Baldassarre 1990, Drake et al. 2001). Marine organisms such as polychaetes, mollusks, and crustaceans are common prey in these zones (Bent 1929, Johnson and Baldassarre 1988, Nicholls 1989). In contrast, during the brood rearing period, piping plovers may consume a higher proportion of terrestrial invertebrates including dipterans and coleopterans (Shaffer and Laporte 1994).

When piping plovers arrive on northern beaches in mid-March (Keane 2002) these terrestrial invertebrates are relatively scarce (L. M. Houghton, Virginia Tech, unpublished data). Thus, the marine organisms obtained on intertidal flats may be particularly important at this time. Nesting near intertidal flats may allow piping plovers to minimize time and energy expended while traveling to feeding areas. This may allow them to spend more time and energy on maintenance, survival, courtship, territorial defense, and egg production.

Intertidal flats and ponds appear to be diminishing resources. They are created when ocean storm waves move across (overwash) barrier islands scouring sand from some areas and depositing it in others (Leatherman 1982) but the frequency of overwashes has been reduced by coastal engineering (Dean 1999). It is important, therefore, to understand the full range of ecological values these zones provide so that the impacts of coastal engineering and habitat management can be accurately evaluated.

We studied plover foraging ecology before nesting on South Monomoy Island, Massachusetts, in 1999 and 2000, to test the hypothesis that intertidal flats and ponds are key piping plover foraging habitats in the weeks prior to nesting. We compared use and availability of different substrates and the foraging rates of plovers within each.

Study Area

South Monomoy was a low-lying sand island between Nantucket Sound and the Atlantic Ocean. South of Chatham, Massachusetts at the southeastern corner of Cape Cod, it was part of the Monomoy National Wildlife Refuge. Like other

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Atlantic sand islands (Leatherman 1982), South Monomoy Island has frequently changed in size and shape due to currents, winds, and waves. During our study, South Monomoy Island was 9.5 km from north to south and 2.0 km from west to east at the widest point, and it was comprised of 655 ha. Unlike most Atlantic barrier islands, South Monomoy Island was a federal wilderness area and has not been subjected to beach nourishment or other large-scale sand manipulations. Thus, it provided an unusual opportunity to observe a coastal ecosystem under close to natural conditions.

Methods

We classified beach areas into 6 zones that were used by piping plovers. Intertidal zones were substrates that were covered by water at high tide and exposed at low tide. Sound intertidal zones were on the Nantucket Sound or west side of the island. Ocean intertidal zones were on the Atlantic Ocean or east side of the island. Tidal-pond intertidal zones included the edges of tidal ponds and the tidal creeks that connected the ponds to Nantucket Sound. Wrack was debris deposited on the beach by tides and was primarily eelgrass (*Zostera marina*). Backshore zones were unvegetated sand, shell, or cobble between the high tide line and the first continuous vegetation or the first escarpment. Open vegetation was herbaceous with >10% and <90% cover and was primarily American beach grass (*Ammophila breviligulata*).

On South Monomoy Island, these zones occurred primarily in bands parallel to one another and to the water's edge. We estimated relative availability of each of the 6 zones with a series of randomly located transects perpendicular to these bands. Starting at the water's edge, we paced the width of each zone until we reached dense vegetation or an escarpment. Each observer calibrated his/her pace by pacing known distances. We measured wrack width to the nearest cm. We calculated percent availability of each zone for each transect by dividing the width of the zone by the total length of the transect.

Time constraints prevented us from obtaining an adequate sample of zone characteristics during the brief prenesting period. We therefore measured these characteristics throughout the breeding season. Because we wanted to examine relative zone use in light of relative zone availability during the prenesting season, we needed to ensure that the zone characteristics measured reflected the conditions that existed then. For that reason, we compared the value of zone variables measured during the prenesting period with those from the rest of the breeding season.

We searched for plovers in March and April, 1999 and 2000. During each complete survey of South Monomoy Island, we surveyed the entire shoreline (20 km), including all beach, intertidal, and sparsely vegetated zones, by walking along the beach and scanning with binoculars or a spotting scope. To minimize tide and observer bias in our surveys, we rotated observers among beach segments and altered the direction traveled from day to day. Because the times of high and low tide at south Monomoy Island advance about 50 min daily, we believe we obtained a representative sample of tide, time of day, and area combinations. We attempted to move at a constant rate, and we stopped only to record data so that the time each zone was searched was roughly proportional to its area. We recorded the zone and behavior of each piping plover observed. Behaviors that we recorded were foraging (pecking, pulling worms, foot trembling; Haig 1992), disturbed (distraction display or running from or toward an intruding plover or other animal), resting (sitting and/or preening), alert (standing upright), moving (flying, walking, running), or courting (displaying, nest excavating, courtship flights, copulation).

We conducted 5-min observations on randomly selected focal birds to estimate foraging rates and to determine if plover time budgets differed by habitat (Altmann 1974, Lehner 1979, Tyler 1979). Foraging rates (attempts/min) have been considered good indicators of shorebird prey availability (Goss-Custard 1977, Pienkowski 1983, Wilson 1990). We observed focal birds from 30 to 150 m with a tripod-mounted Bushnell Spacemaster 40×zoom spotting scope and continuously tape-recorded zone used, behavior, and foraging attempts. We did not select a bird for behavioral or foraging rate observations if we believed, based on flight behavior or directional movement, that we had affected its behavior. If we lost sight of a plover but the zone occupied was known, we recorded zone but not behavior. Later, we played the tape and recorded the zone and behavior at 10-sec intervals. We discarded observations if plovers were out of sight for >100 sec.

We used chi-squared tests to compare the number of plovers in each zone to the number expected if each zone was used in proportion to its availability (Neu et al. 1974, Marcum and Loftsgaarden 1980). We calculated the expected number of plovers in a zone as the mean proportion of a zone on transects × total number of plovers

Table 1. Piping plover foraging rates (attempts/min), beach zone availability ($\bar{x}$ m, $\bar{x}$ %, and 95% CI of zone width), and use (% and 95% CI of piping plovers in each zone), before egg-laying on South Monomoy Island, Cape Cod, Massachusetts, 1999–2000. Chi-square tests were used to determine whether plovers were using zones in proportion to availability. Confidence intervals (95%) were used to determine whether zones were used more or less often than expected based on availability (s = selected, a = avoided).

Habitat	Foraging rates (attempts/min)			Zone availability (m) n = 247 transects		Zone availability (%) n = 247 transects		Zone use while foraging (%) n = 275 plover observations			Zone use while not foraging (%) n = 556 plover observations		
	n[a]	$\bar{x}$	SE	$\bar{x}$ (m)	SE	$\bar{x}$ (%)	95% CI	$\bar{x}$(%)	95% CI	p/a	$\bar{x}$(%)	95% CI	s/a
Ocean intertidal zone	7	13.0	3.4 A	10.8	1.1	18.3	15.3–21.3	2.2	2.1–2.3	a	1.4	1.4–1.5	a
Sound intertidal zone	23	10.5	1.5 A	18.9	4.7	17.9	14.2–21.5	33.8	33.4–34.3	s	5.2	5.1–5.3	a
Tidal-pond intertidal zone	28	8.4	2.1 AB	3.9	1.3	2.6	1.3–3.9	53.5	53.0–53.9	s	5.0	4.9–5.1	s
Wrack	23	3.8	1.0 B	3.0	0.3	10.4	8.4–12.3	7.3	7.0–7.5	a	5.4	5.3–5.5	a
Backshore	83	0.6	0.2 C	19.5	1.3	34.4	31.6–37.1	3.3	3.1–3.4	a	79.5	79.3–79.7	s
Open vegetation	6	0.0	0.0 C	10.4	0.8	16.5	14.4–18.7	0.0	0.0–0.0	a	3.4	3.3–3.5	a
								χ^2 = 2974.32, df = 5, P < 0.0001			χ^2 = 550.44, df = 5, P < 0.0001		

[a] n = number of observations of piping plovers in each habitat; samples were obtained during 164 5-min observations.

observed. We then determined if each zone was used more or less than expected based on 95% CIs of use and availability. If CIs for use and availability overlapped for a zone, we concluded that there was no evidence that the zone was used out of proportion to its availability. If CIs did not overlap, we determined if the zone was used more or less than expected by inspecting the relative magnitude of the use and availability CIs.

We used the Multiple Response Permutation Procedure (MRPP; Cade and Richards 1999) to compare the percent time piping plovers were engaged in different behaviors and to compare foraging rates among zones. We included zones in multiple and pair-wise comparisons if there were ≥3 observations of plovers within the zone.

Results

We searched for plovers on 24 days in 1999 (27 Mar–30 Apr) and observed plovers on 21 of these days. We searched for plovers on 41 days in 2000 (9 Mar–30 Apr) and observed piping plovers on 37 days. We present only behavioral and zone-use data collected in March and April since we found the first nests on 1 May 1999 and 6 May 2000.

We characterized zones on 247 transects from 27 March to 18 August 1999 and 28 April to 5 August 2000. Relative zone widths measured during the prenesting season were similar to relative widths measured during the breeding season for all variables (Wilcoxon 2-sample tests z = 0.22, 1.70, 0.75, 1.66, 1.39, 0.38; P = 0.82, 0.89, 0.45, 0.10, 0.17, 0.70; for ocean intertidal zone, sound intertidal zone, tidal-pond intertidal zone, wrack, backshore, and open vegetation, respectively). We recorded 831 plover observations during island surveys; 275 observations were of foraging plovers and 556 were of plovers that were not foraging (Table 1).

During island surveys, we observed 240 foraging piping plovers (87%) in sound and tidal-pond intertidal zones (Table 1). Only 2% of foraging plovers were in the ocean intertidal zone. Nearly 80% of piping plovers that were not foraging were on the backshore. Use of sound and tidal-pond intertidal zones by foraging plovers peaked near low tide. Use of the backshore by plovers was lowest near low tide (Fig. 1).

Sound and tidal-pond intertidal zones were used by foraging plovers more than expected based on availability. Other zones were used less than expected (Table 1). Backshore was used more than expected by plovers that were not foraging and was the zone used most by these birds. Tidal-pond intertidal zone also was used more than expected by plovers that were not foraging, but it only accounted for 5% of birds observed (Table 1). Foraging rates were highest in sound, ocean, and tidal-pond intertidal zones; intermediate in wrack; and far lower in other zones (n = 170, Table 1).

We based habitat use on 59 5-min observations on 19 days in 1999 and 85 observations on 27 days in 2000. Piping plovers in the sound intertidal zone spent 87% of their time foraging, while those in ocean and tidal-pond intertidal zones spent more than half of their time foraging (Table 2). Birds on the backshore spent >80% of their time resting or alert and only 5% of their time foraging. Those in wrack spent most of their time foraging (43%) or resting (35%).

Discussion

Piping plover distribution and foraging rates indicated that sound and tidal-pond intertidal zones

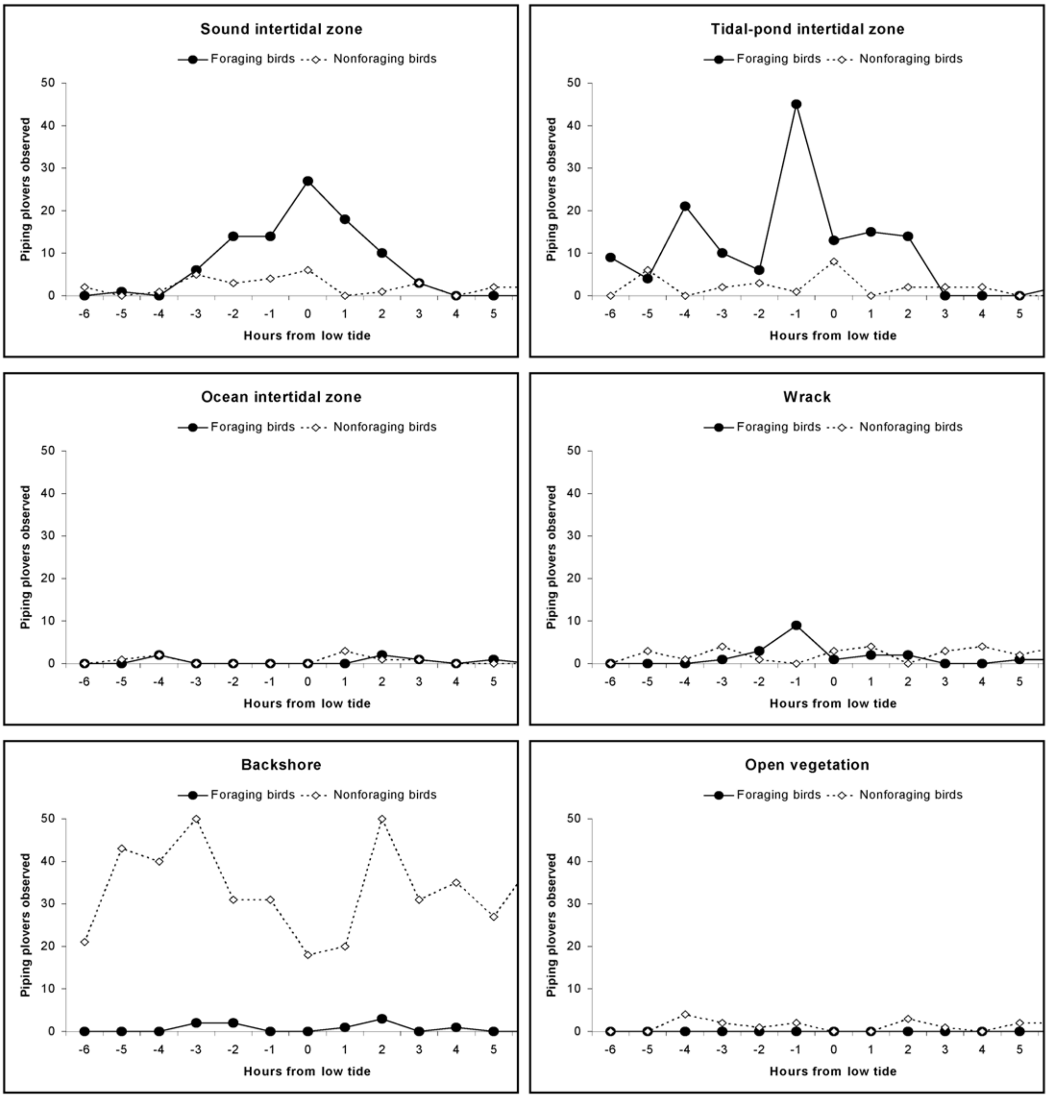

Fig. 1. Number of foraging and nonforaging piping plovers by tidal stage on South Monomoy Island, Massachusetts, USA, 1999–2000.

were important feeding areas in the period before egg-laying. These zones apparently supplied most of the plovers' energy at this time. Rapid but infrequent foraging in the ocean intertidal zone suggests that prey there might have been dense at times but was less consistently available.

Several studies emphasized the importance of these zones as plover habitat during other times of the year. Wintering plovers often forage on protected intertidal areas similar to those used on South Monomoy Island before breeding (Johnson and Baldassarre 1988, Nicholls and Baldassarre 1990, Drake et al. 2001). As at South Monomoy Island, this use is most common at low tide (Johnson and Baldassarre 1988). We frequently observed fledged piping plovers in the sound and tidal-pond intertidal zones after the plover breeding season. Flightless broods with access to such areas also use them more than expected based on availability (Loegering and Fraser 1995, Elias et al. 2000). Thus, tidal flats and ponds may be the primary foraging habitat for Atlantic Coast piping plovers throughout the year.

Five of the 6 zones used by piping plovers (Table 2) were flat open areas, and we assumed that we observed ≥95% of the plovers that were

Table 2. Behavior (% of behaviors) recorded at 10-sec intervals during 5-min behavioral observations of piping plovers in various zones on South Monomoy Island, Massachusetts, USA, 1999–2000. Data are from 144 5-min observations; n = the number of observations of birds in each habitat. Means followed by the same letter are not significantly different from other values in the same column based on Multiple Response Permutation Procedure (MRPP) pairwise comparisons, α = 0.05.

		Foraging		Disturbed		Resting		Alert		Moving		Courting	
Habitat	n	$\bar{x}$ (%)	SE	$\bar{x}$ (%)	SE	$\bar{x}$ (%)	SE	$\bar{x}$ (%)	SE	$\bar{x}$ (%)	SE	$\bar{x}$ (%)	SE
Ocean intertidal zone	7	56.1 B	17.15	0.8	0.75	4.0 BCD	3.52	22.3 B	12.04	16.8	7.57	0.0	0.00
Sound intertidal zone	21	87.2 A	4.23	2.8	1.14	4.8 D	3.56	2.7 C	1.82	2.5	1.60	0.0	0.00
Tidal-pond intertidal zone	27	56.4 B	7.66	4.1	1.65	8.8 D	4.20	20.3 B	5.22	8.6	4.25	1.9	1.51
Wrack	21	43.5 B	10.37	0.9	0.53	35.2 AB	9.57	13.3 BC	6.50	6.7	2.94	0.5	0.48
Backshore	82	5.1 C	2.19	4.3	1.83	28.6 BC	4.11	52.0 A	4.31	7.4	1.96	2.7	1.52
Open vegetation	6	2.8 C	2.78	0.0	0.00	63.7 A	15.07	22.2 AB	13.52	11.4	4.65	0.0	0.00
MRPP test statistic			–25.35,		–1.22,		–6.39,		–12.50,		–0.61,		–0.09,
P [a]			<0.0001		0.11		<0.0001		<0.0001		0.23		0.27

[a] P-value is for the Multiple Response Permutation Procedure (MRPP) test of differences within the column.

present during our surveys. The exception was open vegetation, which may have concealed some plovers. However, we rarely flushed prenesting plovers when walking through open vegetation, and we rarely observed piping plovers flying or walking into open vegetation. This supported our view that open vegetation zone was infrequently used during the prenesting period. Nevertheless, our estimates of the proportion of use received by open vegetation zone may be low. A study using radiotelemetry would produce an unbiased estimate of the frequency of use of sparse vegetation.

Backshore areas used during the prenesting period were eventually used for nesting and were closer to sound or tidal-pond intertidal zones than areas where plovers did not nest (Keane 2002). Placing nests near these foraging areas allowed plovers access to reliable food sources while minimizing travel time and maximizing the opportunity to defend territories.

The peak of plover use at the lower tide levels probably occurred because more food was available in the lower parts of the intertidal zone. The density of benthic organisms varies with elevation (Peterson 1991), and many organisms are most abundant in the lower reaches of the zone (Raffaelli et al. 1991). It also is possible that prey were more susceptible to plover predation near the edge of the receding tide, due to behavior or position in the sediment column. The details of distribution and abundance of benthic organisms on South Monomoy Island, and prey selection by plovers there, remain to be studied. If increased use at lower tides simply was a function of more tidal flat being exposed, we would expect plovers to be distributed approximately uniformly throughout the zone. In fact, the plovers concentrated along the receding edge of the water. On south Monomoy Island, the length of this edge did not change substantially as the tide height changes.

Management Implications.—The tidal flats and ponds selected by piping plovers were created during storm-caused overwash or other erosional processes (Leatherman 1982). Beach management efforts aimed at protecting human property reduce the number and extent of these overwashes (Dean 1999) and therefore reduce the extent of key intertidal foraging habitats. Piping plover management can be improved by increasing the number and size of bayside intertidal flats either by allowing their formation by natural processes or by active sediment management.

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